Fast Visible and Infrared Diagnostics for NSTX

R. J. Maqueda and G. A. Wurden

P-24 Plasma Physics Group
Los Alamos National Laboratory

Presented at the FY98 NSTX Research Forum
December 3-5, 1997
Princeton Plasma Physics Laboratory

- Fast visible imaging system.
- Infrared imaging system.
- High-speed spectroscopically-resolved viewing chords.

Los Alamos
NATIONAL LABORATORY

Plasma Physics

Fast visible imaging system

- **Desired measurements**
  - overall edge plasma dynamics
  - visible edge phenomena: fluctuations, MHD perturbation of edge plasma, influx of impurities and fuel [both spontaneous (i.e. recycling, blooms, etc.) and deliberate (i.e. pellets, DOLLOP, puffs, fast scanning probes, etc.), IRE/disruptions (precursors and aftermath), UFOs, runaway electrons (cyclotron radiation and interaction with walls), etc.
  - coaxial helicity injection gun plasma: gas breakdown and dynamics, influx of impurities and fuel, etc.
- **Approach**
  - Use a Kodak EktaPro fast visible digital video camera with substantial flexibility in the obtainable views of the torus.
  - Use intensifier on camera to allow short exposures/frame rates while using narrow-band interference filters.
  - Use two imaging fiber bundles to couple camera to torus.

Fast imaging diagnostic components

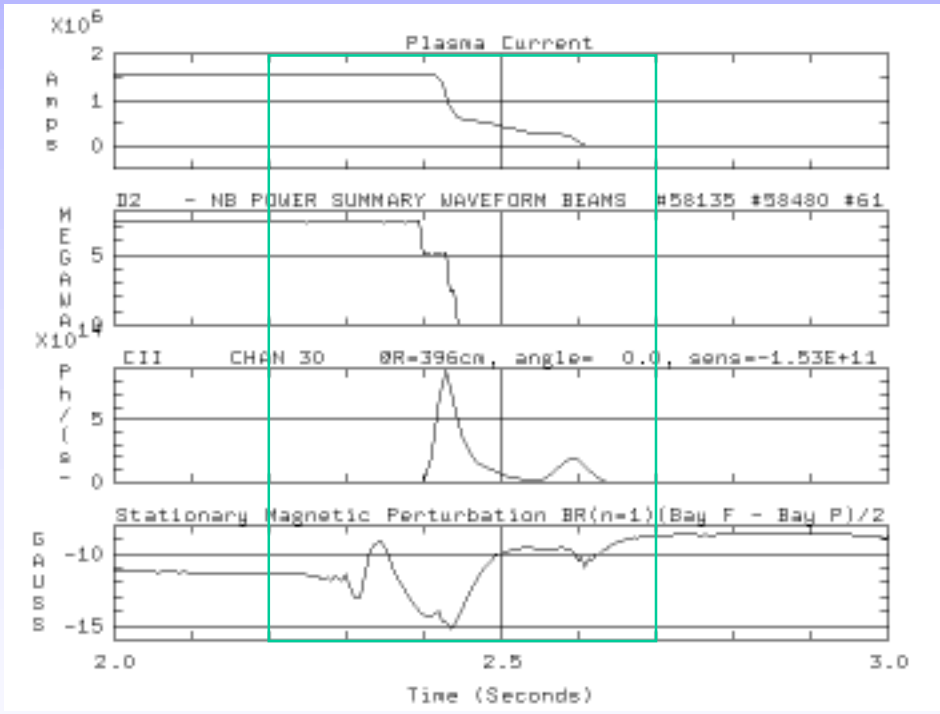
- Intensified Kodak EktaPro EM1012 camera system:
  - Intensified imager
  - Intensified imager controller
  - Motion analyzer processor
- Fiber optic links for processor control (GPIB link) and analog video signal transmission.
- Intel based computer running a LabView virtual instrument controller, either under Windows NT or Windows 95.
- VCR for analog data storage.

Fast visible imaging system use in TFTR

- A visible imaging system was previously used at TFTR where numerous visible phenomena were recorded and studied. These phenomena include: disruptions, runaway electron effects, lithium injection by means of pellets and DOLLOP, and edge band structures.

  Video clips obtained from TFTR can be seen at:
  http://wsx.lanl.gov/ricky/disrupt.htm

- **Example:** Shot 103681
  Disruption triggered by “locked mode” or “SMP”



Camera operated at 2000 frames per second with 30 μs exposure of each frame and no interference filter.

Concept design for NSTX's fast visible imaging system

- Two imaging fiber bundles couple the camera/intensifier to the torus.
- A remote controlled mirror allows the selection of which bundle is imaged into the camera.
- A remote controlled filter wheel is placed between the bundle selector and the camera.
- One of the bundles has its machine end fixed to a midplane viewing port while the other bundle is movable between viewing ports according to the desired use.
- The "fixed" bundle is provided of a remote controlled end assembly that performs lens selection (for 4 different fields of view), focusing and steering.
- The "movable" bundle has a smaller size end assembly with only remote controlled focusing. The field of view of this bundle can be changed manually.

Fast camera options

Camera system	EktaPro 1012	EktaPro HS4540
Frame rate (full frame)	1000 Hz	**4500 Hz**
Maximum frame rate (partial frame)	6000 Hz	**40500 Hz**
Resolution (full frame)	239 x 192 pixels	256 x 256 pixels
Dynamic range of detector	8 bit	8 bit
Minimum exposure	10 μs	**20 ns**
Frame storage	1638 full frames	**5120 full frames**
Spectral range	440-700 nm	**180-850 nm**
Status	LANL owned	To be purchased
NSTX availability	Partial to full time	**Full time**

Infrared imaging system

- **Desired measurements**

  - Heat loads on plasma facing components including the “divertor” area, the coaxial helicity injection gun, and the RF antenna.
  - Localization of hot spots, possible sources of impurities.
  - Possible localization of effects of fast particle losses.

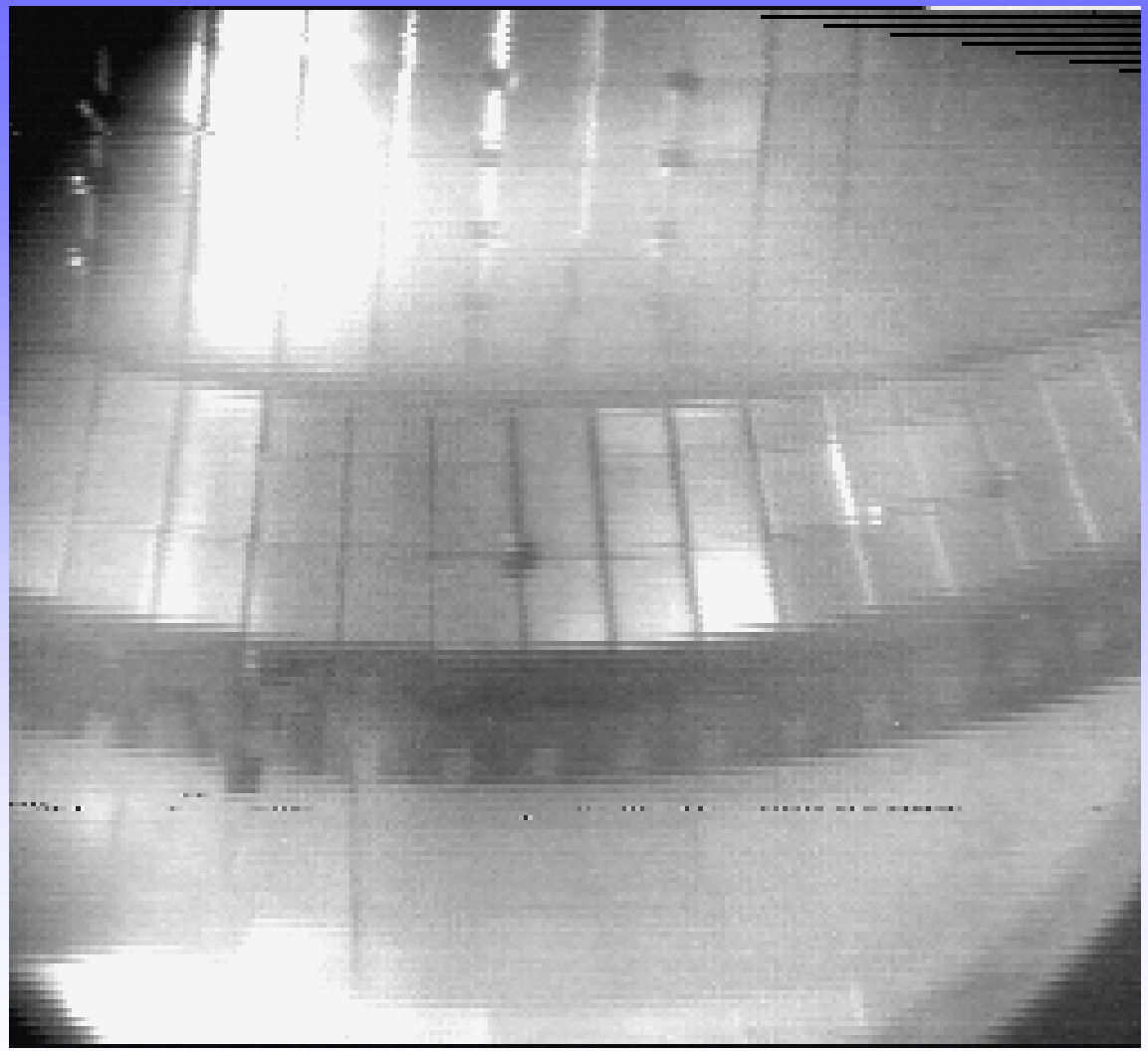
- **Approach**

  - Use an Amber Radiance video camera sensitive in the mid IR range: 3-5 μm.
  - Use an IR periscope based in ZnSe optics to transport the image to the IR camera.
  - Use removable steering mirrors on the machine end of the periscope to obtain different views the torus walls.

Amber Radiance 1 IR camera

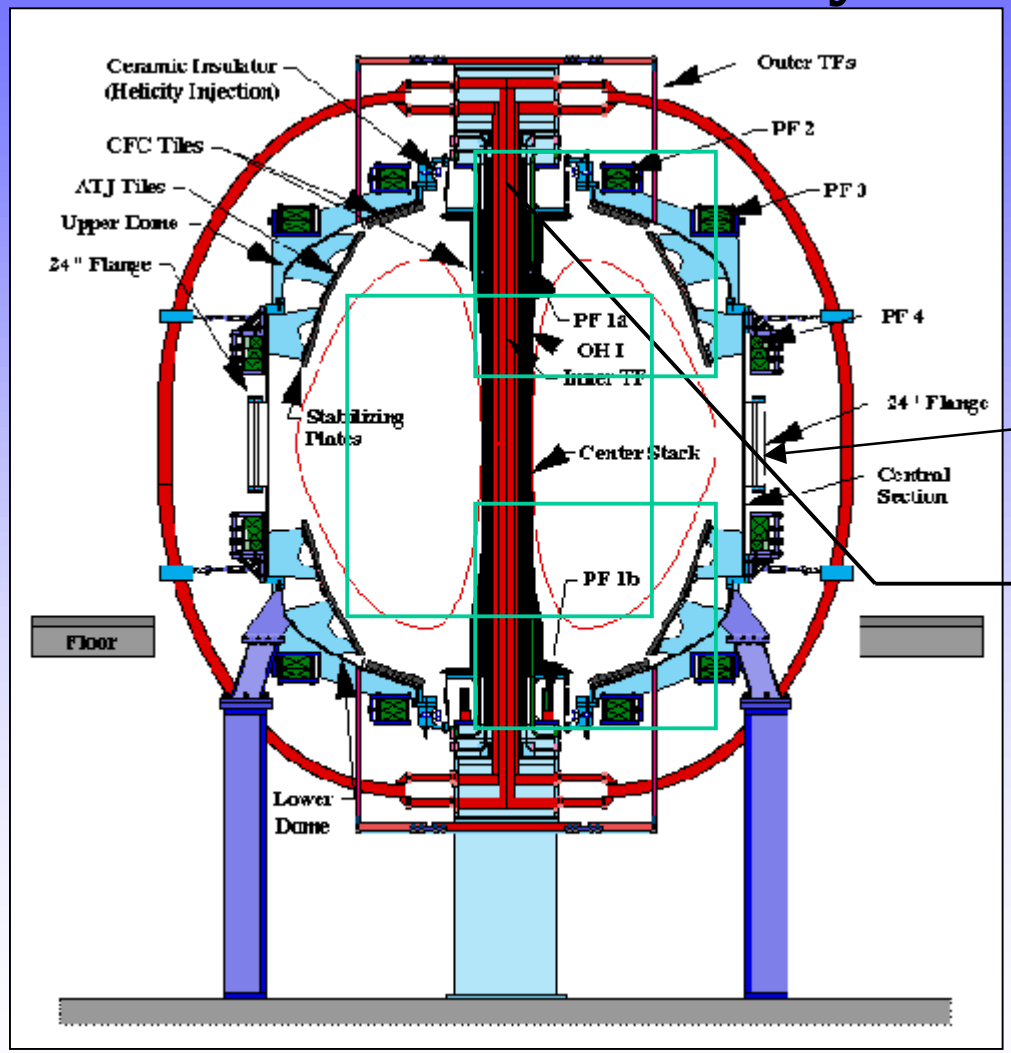
- Sensitivity range: 3-5 μm.
- 256 x 256 element focal plane array.
- Gated from <10 μs to 16 ms.
- Full remote control through RS-232 link.
- 2.23°/7.4° Dual Field of View lens.
- Filter wheel with narrowband or 10%, 1% , and 0.1 % neutral density filters.
- NTSC, S-Video or 12 bit digital output.

IR image of C-Mod's lower divertor



- Bay A section of the lower divertor is viewed from the top through re-entrant periscope.
- Electron Cyclotron Discharge Cleaning (ECDC) heats the plasma facing components of the divertor.
- Slots between molybdenum tiles can be clearly seen indicating better than a few millimeters spatial resolution.

Concept design for NSTX's IR imaging system



Remote controlled mirror wheel to obtain three different views. Sapphire windows are used as vacuum interfaces.

IR camera

ZnSe based IR periscope with remote controlled focusing capabilities.

Dual field of view lens on IR camera allows for a x3 magnification without any change in the periscope optics. A 2D positioning device is used below the camera to select which portion of the image is magnified.

IR camera options

Camera system	Radiance 1	Radiance HS
Frame rate (full frame)	60 Hz	**120 Hz**
Maximum frame rate (partial frame)	Not available	**1400 Hz**
Resolution (full frame)	256 x 256 pixels	256 x 256 pixels
Dynamic range of detector	12 bit	12 bit
Frame exposure	Progressive	**Snapshot**
Spectral range	3-5 μm	3-5 μm
Status	LANL owned	To be purchased
NSTX availability	Part time	**Full time**

High-speed spectroscopically-resolved viewing chords

- **Desired measurements**

  - Flexible system for use in high-speed, spectroscopically-resolved measurements of the edge plasma and coaxial helicity injection gun. These can include fast fluctuation studies and Doppler shift measurements of plasma rotation.

- **Approach**

  - Use an existing high-gain shoebox array of detector.
  - Use existing 400 kHz bandwidth digitizers (Lecroy 6810) at 1 MHz sampling rate.
  - Use interference filters or an existing high resolution spectrometer for wavelength selection. This can be configured in two modes: either multi-fiber input and single-wavelength output or else single-fiber input and multi-wavelength output.
  - Use up to 16 optical fibers to couple viewing chords to rest of the diagnostics.

Summary

- LANL is interested in collaborating on NSTX and we have identified three possible diagnostics to be fielded, operated and data analyzed as part of this collaboration.
- We bring collaboration experience in national and international magnetic fusion experiments, including ASDEX, TFTR, C-Mod, JT-60U, and LHD.
- We bring experience in development, installation, operation, and data analysis of MFE diagnostics: bolometers, IR and visible imaging systems, neutron detectors, spectroscopic arrays, etc.